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DENSITY SPECTRUM OF THE PENETRATING COMPONENT OF EXTENSIVE ATMOSPHERIC SHOWERS

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DENSITY SPECTRUM OF THE PENETRATING COMPONENT OF EXTENSIVE ATMOSPHERIC SHOWERS

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ABSTRACT: Determination of the density spectrum exponent of the muon component of extensive air showers on a hodoscopic assembly composed of four sets of Geiger-Muller counters with a 30-cm lead absorber. Found by the maximum likelihood method from a total of 7,109 recorded events, the value of the exponent was 2.27 plus or minus 0.08 in a shower with a mean total muon number equal to or greater than 1.2×10^6, measured at an altitude of 2,925 m above sea level.

Introduction /1529*

For determining the parameter γ of the power law

$$D(x) = ax^{-(\gamma+1)}dx, \tag{1}$$

which describes with sufficient accuracy the differential spectrum of the density of the penetrating component of extensive atmospheric showers on the basis of experimental data obtained using detectors shielded with a thick absorber, it is necessary to take into account multiplication processes in the absorber. In actuality, as a result of generation of local electron-nuclear showers and δ-showers from the nuclearly active and μ-meson components of extensive atmospheric showers respectively, the density and distribution of particles in the space beneath the absorber change greatly. It is easy to demonstrate at if no allowance is made for multiplication processes, the values obtained for γ will be lower than the true value; this difference is dependent on the type of experimental apparatus and is never equal to 0.

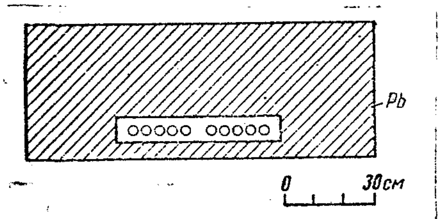
The presently known values of the exponent γ [1-6] were obtained without taking into account particle multiplication processes. This can explain to a considerable degree the considerable discrepancy in the results published by different authors. On the other hand, on the basis of models of extensive atmospheric showers formulated during recent years it is now possible to

*Numbers in the margin indicate pagination in the foreign text.

obtain new information on primary cosmic radiation in the region of super high energy by studying the μ-meson and nuclear active components.

Experimental Apparatus

The registry of the penetrating components of extensive atmospheric showers was with a system of four groups of counters A, B, C, D, situated in the horizontal plane at the corners of a square with sides 8 m in length. Each group consisted of 10 identical Geiger-Muller counters 38 mm in diameter and with an effective area of 320.04 cm^2. The counters were placed in a lead container (see Figure). The thickness of lead above the counters was 30 cm.



Quadruple coincidences were registered (resolving time 3 μsec), during which at least one counter in each group was triggered. All the counters were connected to a hodoscope. The above-mentioned quadruple coincidence was the pulse controlling the hodoscopic system. The resolving time of the hodoscopic system was 15 μsec, whereas the probability of random triggering of the counter with a controlling pulse was ~0.01. A measurement was made at an elevation of 2,925 m about sea level at the Musala Cosma Ray Station. The frequency of coincidences at the observation level was about 1 $hour^{-1}$.

Method for Processing Data and Results /1530

The plate and postal number of triggered counters in the apparatus was determined for each registered extensive atmospheric shower. Using 7,109 registered cases, we computed the mean number of triggered counters:

$$\bar{n} = \sum_{n=4}^{40} nC(n) \Big/ \sum_{n=4}^{40} C(n), \qquad (2)$$

where C(n) is the number of cases for Rn triggered counters ($4 \leqslant n \leqslant 40$). It can be demonstrated [7] that if interaction processes in the absorber are neglected the expected $\bar{n}$ value will be dependent on the exponent γ as follows

$$\bar{n} = \frac{40[3(11^{\gamma} - 10^{\gamma}) - 3(21^{\gamma} - 20^{\gamma}) + 31^{\gamma} - 30^{\gamma} - 1]}{40^{\gamma} - 4\cdot 30^{\gamma} + 6\cdot 20^{\gamma} - 4\cdot 10^{\gamma}}. \tag{3}$$

On the basis of (2) and (3), a value 1.24 ± 0.02 was obtained for γ.

In accordance with the above, the generation of local electron-nuclear showers and δ electron increases the particle density in the space beneath the absorber. According to expression (3), a lesser γ value corresponds to a greater $\langle\bar{n}\rangle$ value; therefore, it must be assumed that this value is lower than the true value.

In order to check this assumption, all the registered cases were broken down into five independent subgroups. Subgroup V, or to our terminology, Class-V events, included those cases when there were at least four untriggered counters between the triggered counters in some of the groups A, B, C, D, as well as those cases when only one counter was triggered in all the groups. Class IV includes events which do not fall into Class V and for which there are at least three untriggered counters between the triggered counters. Class III includes cases which do not fall into Classes IV and V, in which there are at least two untriggered counters between the triggered counters. Class II includes those cases not falling in the preceding classes and for which there is at least one untriggered counter between the triggered counters. Class I includes all other events.

TABLE 1.

"Class"	I	II	III	IV	V	Total
No. of events	5782	348	192	101	681	7104

TABLE 2.

Class	I	II	III	IV	V	Mean value for classes II-V
γ	1,23±0,02	2,37±0,13	2,17±0,24	3,09±0,34	2,12±0,12	2,27±0,08

The exponent γ for events from Classes II to V inclusive was determined by the distribution of events in dependence on the triggered counters by two methods: a) by comparing the predicted and experimentally determined mean number of triggered counters, and b) by the maximum probability method. For events in Class I, due to some computation difficulties, we employed only method a). It was established that the values obtained by both methods do /1531
not differ from one another within the limits of statistical error.

Table 2 gives values found by method b) (except for events in Class I).

Discussion of Results

The criterion for selection of data into classes used in this study takes into account the fact that multiplication processes in the absorber with a high probability govern the triggering of adjacent counters and that the probability of triggering of widely based counters is negligible. Accordingly it must be expected that with an increase in the number of the class, the determined value of the exponent γ will be asymptotically free from the multiplication effect. The values of the γ parameter for events from Classes II to V are statistically indistinguishable and different substantially from the values for Class I, in which there must exist events with adjacent triggered counters. This gives basis for computing the mean γ value for Classes II-V, for which we found: $\gamma=2.27 \pm 0.08$.

It is clear that cases of extensive atmospheric showers whose axis are situated distant from the apparatus must be assigned to the second and higher classes. This statement can be backed up with a high probability (~93%) for the inelastic interaction of a nuclearly active particle incident on a lead absorber 30 cm thick, shielding counter. That is why it can be assumed that the determined exponent must be attributed to the μ-meson component of extensive atmospheric showers.

The mean density of showers registered with the apparatus is estimated at 3.6, 3.2, 2.0 and 1.9 penetrating particles per square meter for events in Classes II, III, IV, and V respectively. Assuming that this is the μ-meson density, the number of μ-mesons in the registered showers is $\overline{N}_\mu \gtrsim 1.2 \cdot 10^6$.

A total of 20,000 already registered events are now being processed; these will considerably increase the accuracy in determining γ.

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